

67075
Crushed Anorthosite
219 grams

DRAFT



Figure 1: Tray full of 67075. NASA S 72-37541. Cube is 1 inch.

Introduction

Lunar sample 67075 is very friable (figure 1). The original PET description (LSPET 1973) was that of a crushed anorthosite with evidence of some flow (figure 2) and some recrystallization in the solid state (120 deg. triple junctions, figure 3). Detailed petrographic description showed that the sample was a mixture of closely related anorthositic rocks from a layered igneous intrusion (McCallum et al. 1975). Chemical analyses show a range of Al_2O_3 (31-34%) and FeO (1-4%) contents.

67075 was originally collected as two broken parts of a conspicuous white rock on the lunar surface near the rim of North Ray Crater (Sutton 1991). During transit to Earth it broke into numerous pieces, such that lunar orientation and zap pits on original surface can no longer be discerned. It has proven difficult to date,

but is apparently about 4 b.y. old, with about 50 m.y. exposure to cosmic rays.

Petrography

Pecket and Brown (1973), Brown et al. (1973) and McCallum et al. (1975) all suggest that 67075 was assembled from genetically-related fragments of a layered plutonic anorthosite complex. This explanation

Mineralogical Mode for 67075

	McCallum et al. 1975	Steele and Smith 1973
Plagioclase	90 %	99
Pyroxene		70
Olivine		1
Ilmenite		30

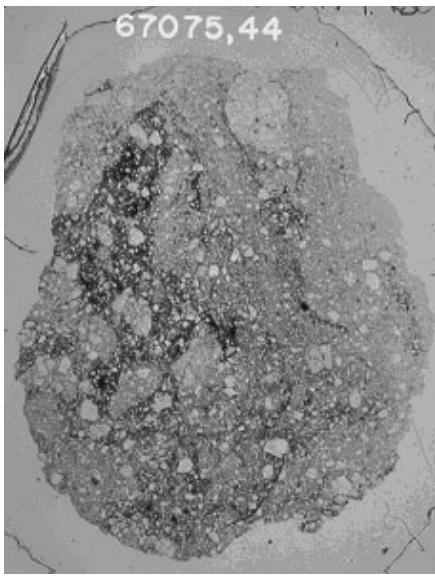


Figure 2: Thin section of one of the small fragments from the tray (figure 1). NASA S72-52492. This is about 1 cm.

can explain the pyroxene exsolutions and the range of compositions of mafic minerals (Ryder and Norman 1980). Nord et al. (1975) showed that 67075 was “lithified” or cemented by a mild shock-heating event – such as the North Ray Crater impact.

Mineralogy

Olivine: Brown et al. (1973) and McCallum et al. (1975) reported Fe-rich olivine (Fo_{44-55}). Smith and Steele (1975) determined trace elements in olivine.

Pyroxene: Steele and Smith (1973), Brown et al. (1973), Dixon and Papike (1975), McCallum et al. (1975) and others studied the exsolution of pyroxene fragments in 67075, including the inverted pigeonite (figure 4 and 5).

Plagioclase: Brown et al. (1973), Steele and Smith (1973), Dixon and Papike (1975) and McCallum et al. (1975) reported calcic plagioclase (An_{93-97}) in 67075. Meyer et al. (1974), Meyer (1979), Hansen et al. (1989) and Steele et al. (1990) studied the trace element content of plagioclase (An_{97}). Gose et al. (1975) studied cation ordering.

Chromite: El Goresy et al. (1973) reported two distinct occurrences of spinel: primary Ti-chromite and breakdown of ulvöspinel. Okamura et al. (1976) studied spinel lamallae exsolved from augite.

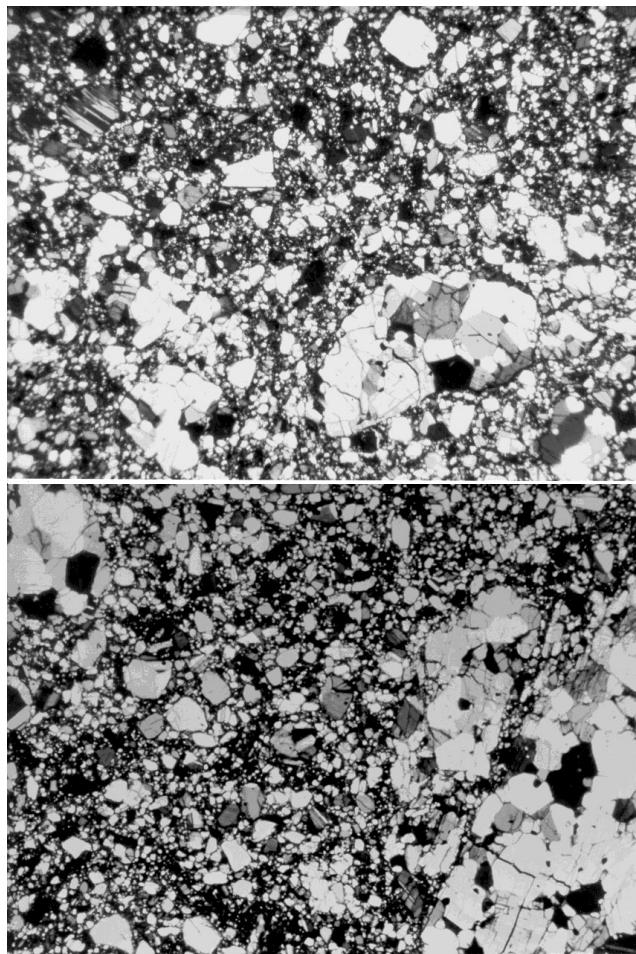


Figure 3: Thin section photomicrographs of 67075 with cross polarized light. NASA S72-42278 and NASA S72-42274. About 2.5 mm across.

Chemistry

The chemical analyses of splits of 67075 show a slight variation in mafic mineral content but similar REE content (Haskin et al. 1973, Hubbard et al. 1974, Scoon 1974, Wanke et al. 1975 and Lindstrom et al. 1981). The analysis by Hertogen et al. (1977) showed a very minor meteoritic siderophile content.

Radiogenic age dating

67075 was dated by the $^{39}\text{Ar}/^{40}\text{Ar}$ plateau technique as 4.04 ± 0.05 b.y. (figure 8)(Truner et al. 1973). Huneke et al. (1977) could not obtain a good plateau, but the plagioclase may be 3.95 b.y. (figure 9).

Silver (1973abs) noted excess Pb in 67075 that was apparently “unsupported” by the U and Th. Oberli et al. (1979abs) obtained Pb isotope values closer to the isochron defined by the cataclysm. Lead isotopes in

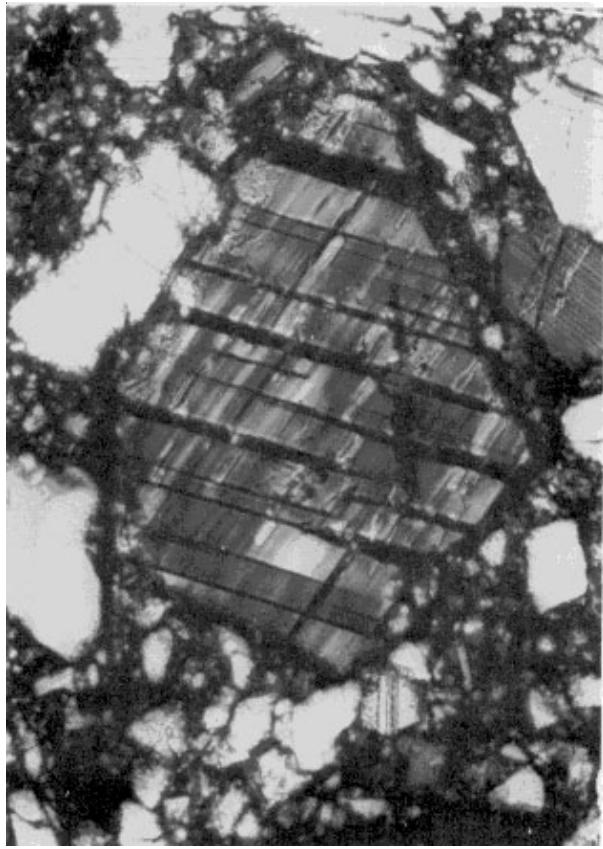


Figure 4: Photomicrograph of pigeonite crystal with coarse exsolution of augite lamellae in 67075,48. Crystal is 200 microns long (this is figure 1 in Brown et al. 1973a).

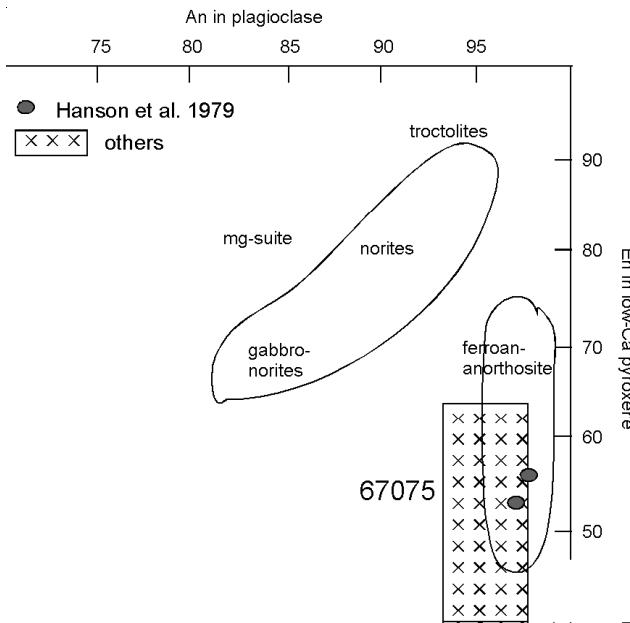


Figure 6: Field of plagioclase and pyroxene composition of clasts in 67075. Pyroxene and plagioclase have not been studied as pairs in 67075.

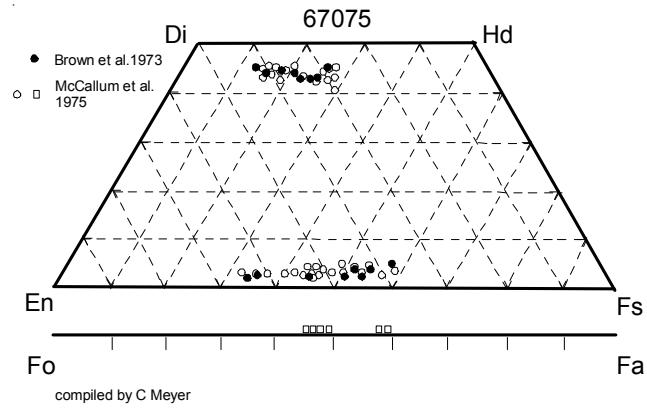


Figure 5: Pyroxene and olivine composition in 67075. Pyroxene is exsolved, but also present as individuals (data from Dixon and Papike 1975, McCallum et al. 1975 and Brown et al. 1973a).

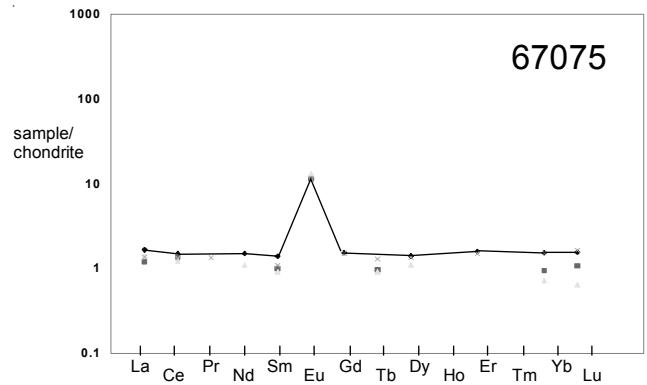


Figure 7: Normalized rare-earth-element diagram for 67075 (isotope dilution data by Hubbard et al. 1974 is connected). Additional data by Wanke et al., Haskin et al., Lindstrom et al.(table 1) are plotted as colored dots.

67075 were again studied by Premo et al. (1989) who found that the data defined two intercepts with Concordia at 4.09 and 4.35 b.y. (figure 10).

Nyquist et al. (1976) produced a Rb/Sr isochron diagram (figure 11).

Cosmogenic isotopes and exposure ages

Turner et al. (1973) reported a ^{38}Ar exposure age of 46 m.y., Marti et al. (1973) reported the ^{81}Kr exposure age of 48.5 ± 5.5 m.y. and Hohenberg et al. (1978) calculated 50.2 and 49 m.y. exposure ages.

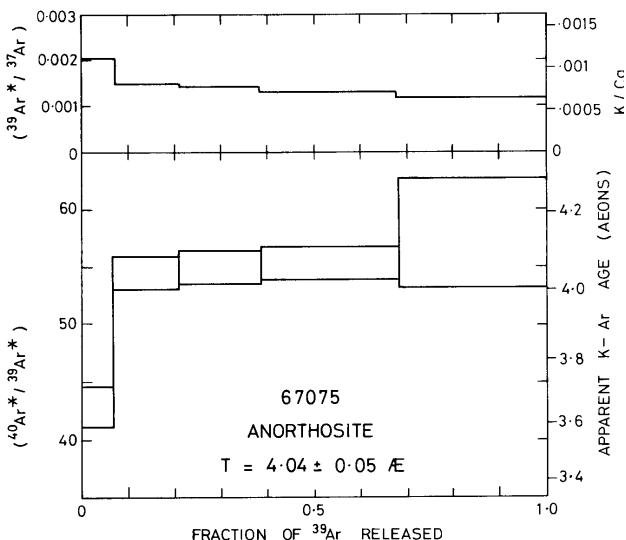


Figure 8: Apparent age and K/Ca as a function of ^{39}Ar release from cataclastic anorthosite 67075 (coarse plagioclase). Turner et al. 1973.

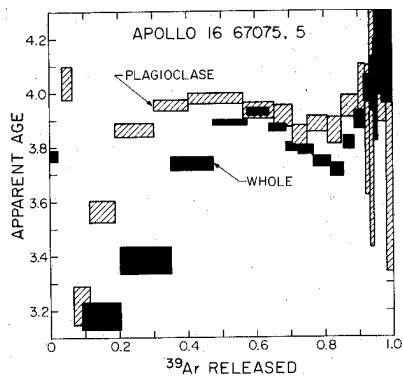


Figure 9: Ar release diagram for plagioclase and whole rock splits of 67075 (Huneke et al. 1977abs).

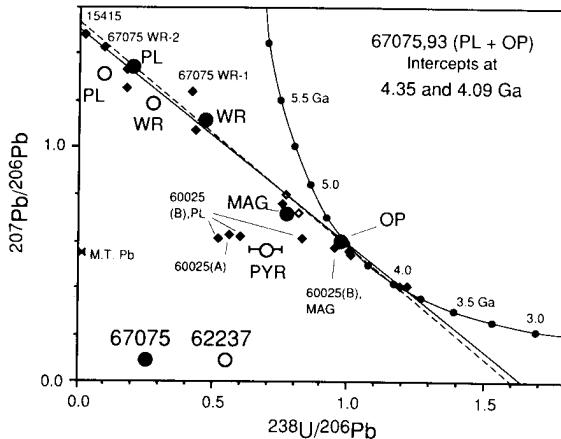


Figure 10: U/Pb isochron diagram showing data for 67075 (from Premo et al. 1989).

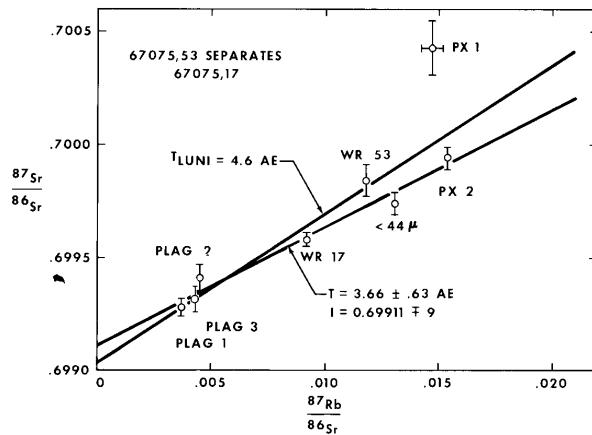


Figure 11: Rb/Sr isochron diagram for 67075 (from Nyquist et al. 1976).

Other Studies

Weeks et al. (1973) elec. Paramagnetic resonance

Lightner and Marti (1974) Xe

Drozd et al. (1977) Xe

Summary of Age Data for 67075

	Ar/Ar	Pb/Pb	Rb/Sr
Truner et al. 1973	4.04 ± 0.05 b.y.		
Huneke et al. 1977	3.95 ± 0.1 b.y.		
Silver 1973abs			
Oberli et al. 1979abs		4.47 (model age)	
Premo et al. 1989		intercepts at 4.09 and 4.35 b.y.	
Nyquist et al. 1976			3.66 ± 0.63 b.y.
Caution: ages have not been corrected for new decay constants			

Table 1. Chemical composition of 67075.

reference weight	LSPET73	Hertogen77	Hubbard74	Lindstrom81	Haskin 73	Scoon 74	Wanke 75
SiO ₂ %	44.9	(a)			45.5	44.42	(e) 45.35
TiO ₂	0.09	(a)			0.05	0.11	(e) 0.1
Al ₂ O ₃	31.54	(a)		32.1	(d) 34.2	31.73	(e) 31.18
FeO	3.41	(a)		2.94	(d) 1.07	3	(e) 3.95
MnO	0.06	(a)		0.046	(d) 0.017	0.04	(e) 0.06
MgO	2.42	(a)		2.3	(d) 0.47	2.35	(e) 3.13
CaO	18.09	(a)		18	(d) 19.9	18.12	(e) 17.11
Na ₂ O	0.26	(a)		0.28	(d) 0.34	0.27	(e) 0.26
K ₂ O	0.01	(a)	0.016	(c)	0.0233	0.03	(e) 0.014
P ₂ O ₅						0.04	(e) 0.02
S %	0.01	(a)				0.01	(e)
<i>sum</i>							
Sc ppm				4.73	(d) 1.89	(d)	7.68
V							(d)
Cr	420	(a)	372	(c) 351	(d) 119	(d) 457	(e) 560
Co				6.42	(d) 1.63	(d)	7.34
Ni	<4	(b)			1	(d)	
Cu							13.2
Zn	6.36	(b)			<1	(d)	15
Ga					3.14	(d)	2.33
Ge ppb		3.2	(b)				
As						2	(d)
Se		3.1	(b)				
Rb	0.8	(a) 0.4	(b) 0.593	(c) 162	(d) 0.63	(d)	0.67
Sr	144	(a)	145	(c)			127
Y	2.5	(a)					(d)
Zr			7.06	(c)			
Nb							
Mo							
Ru							
Rh							
Pd ppb		<0.4	(b)				
Ag ppb		0.25	(b)				
Cd ppb		0.43	(b)				
In ppb		0.48	(b)				
Sn ppb							
Sb ppb		0.071	(b)				
Te ppb		<5	(b)				
Cs ppm		0.03	(b)		0.037	(d)	0.03
Ba			8.85	(c) 6	(d)		13
La			0.393	(c) 0.285	(d) 0.33	(d)	0.32
Ce			0.891	(c) 0.82	(d) 0.75	(d)	0.8
Pr							0.12
Nd			0.664	(c)	0.5	(d)	
Sm			0.209	(c) 0.145	(d) 0.135	(d)	0.16
Eu			0.65	(c) 0.646	(d) 0.73	(d)	0.63
Gd			0.301	(c)			0.3
Tb				0.035	(d) 0.033	(d)	0.047
Dy			0.343	(c)	0.226	(d)	0.33
Ho							(d)
Er			0.255	(c)			0.24
Tm							(d)
Yb			0.251	(c) 0.155	(d) 0.117	(d)	0.25
Lu			0.038	(c) 0.026	(d) 0.0157	(d)	0.04
Hf			0.12	(c) 0.064	(d) 0.055	(d)	0.12
Ta							0.011
W ppb							0.015
Re ppb		0.02	(b)				(d)
Os ppb		0.3	(b)				0.2
Ir ppb		0.319	(b)				(d)
Pt ppb							
Au ppb		0.048	(b)			0.66	(d)
Th ppm				0.023	(c)		
U ppm		0.0206	(b)	0.013	(c)	0.0052	(d)

technique: (a) XRF, (b) RNAA, (c) IDMS, (d) INAA, (e) classical wet

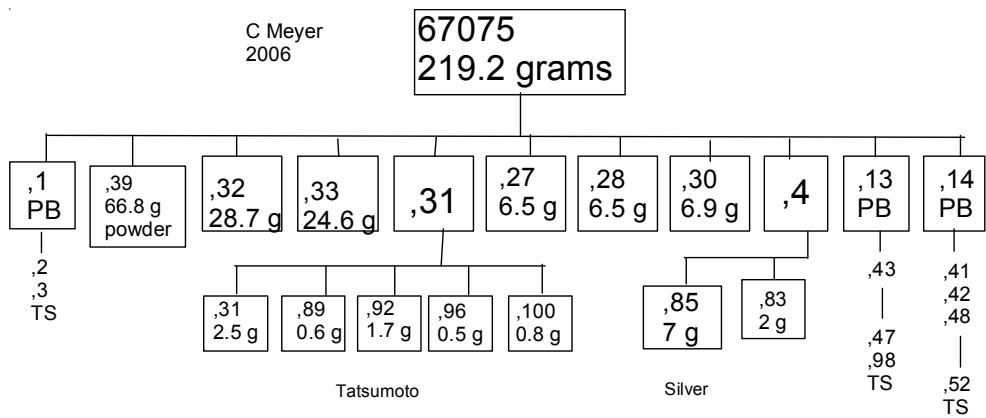


Table 2. Composition of 67075 cont.

	U ppm	Th ppm	K2O %	Rb ppm	Sr ppm	Nd ppm	Sm ppm	technique
Premo 89	0.00618	0.0156						idms
Nyquist et al. 1976				0.499	158			idms
				0.593	145			idms
Wanke 75	0.0052		0.014	0.67	127		0.16	RNAA
Oberli 79	1.852	13.67						idms